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Energy Consumption and Economic Development in Malaysia: A Multivariate Cointegration Analysis

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Abstract

Taking into accounts for the dual role of energy in the demand and supply, this paper develops a vector error-correction model (VECM) to test for the existence and direction of causality between energy consumption and economic development in Malaysia. Using the Johansen cointegration technique, the results indicate that the long-run movements of economic development, energy price, the structure of economy, capital, labour and energy use in Malaysia are related by two cointegrating vectors. Further, the results show that there is directional causality running from economic development to energy consumption. Hence, an important policy implication of this study is that energy saving would not harm economic development in Malaysia.

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Keywords : Energy consumption; economic development; causality; vector error correction model

1. Introduction

In recent years, a great number of empirical studies have dealt with different aspects of energy consumption and economic development issues using both theoretical and empirical evidence. The review of literature states that a relationship exists between energy consumption and economic development. However, when it comes to whether energy use is a result of, or a prerequisite for, economic development, there are no clear conclusions in the literature.

Currently, there are four views exist regarding the causal relationship between energy consumption and economic development. The first view argues that most of the literature on energy and economic development discusses how development affects energy use rather than vice versa (see for example,

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Toman and Jemelkova (2003)). This strand of literature considers economic development as the main driver for energy demand that is as the economy grows the demand for energy of the economy increases. In contrast to the first view, Stern and Cleveland (2004) have stressed the importance of considering energy as an essential factor of production in addition to capital, labour and materials and thus suggested that energy is necessary for growth. The third view contends that both energy consumption and economic development cause each other, i.e. that there is a bi-directional causality between energy consumption and economic development. The fourth view argues that there is no causal relationship between energy consumption and economic development. In other words, both energy consumption and economic development are neutral with respect to each other.

Although a number of studies have been conducted on the causal relationship between energy consumption and economic development, the empirical results however, have shown a lack of consensus among economist. One problem is that most of these studies have ignored the important dual role of energy in both demand and supply side, thus suffer from omission variable bias such as the capital stock, energy prices and labour. Empirically, Loganathan and Subramaniam (2010) who examined the relationship in Malaysia found evidence of bidirectional causality between energy consumption and economic development. On the other hand, Ang (2008), who also examined the relationship between energy consumption and economic development in Malaysia, found that causality is running from economic development to energy consumption. The results, which are contradictory, illustrate that one should be cautious when drawing policy implications with the aid of bivariate causality tests and neglecting the dual role of energy in demand and supply side.

Therefore, the purpose of this paper is to fill the gap by studying the causality between energy consumption and economic development using multivariate models, which are closer to economic theory. The framework for the analysis is the economic interaction between the supply side of the economy, with an associated production function, and energy demand. On the supply side, energy, labour and capital are considered to be important factors for generating GDP. On the demand side, GDP, energy price and level of industrialisation are the determinants for energy consumption. The Vector Error Correction Model (VECM) approach used in this paper allows all these variables to be endogenous, thereby allowing for additional channels of causality. For example, it allows for both energy and GDP to have a causal relationship with a third endogenous variable, without restricting the direction of this relationship. This would explain the correlation between GDP and energy without implying that there is a causal relationship between the two. Another advantage of the approach taken in this paper is that it models both the supply and the demand sides of the economy, allowing therefore for two cointegrating relationships.

The rest of the paper is structured as follows. Section 2 presents the literature review. Section 3 deals with the empirical model specification and the econometric methodology. Section 4 reports the empirical results and Section 5 concludes with some policy implications.

1. Literature Review

The literature concerning the linkages between energy and the economy have been addressed in several ways, which largely reflect the theoretical background of each approach and the scope of each analysis. Within the neoclassical theory of economic growth, the focus has been on the interaction between energy, technical progress, productivity as well as examining the substitutability or complementarity between energy and other factors of production. In the traditional literature, Berndt and Wood (1975), Griffin and Gregory (1976) and view energy as an important input in the production process of the industrial sector since energy commodities are used to support several of its activities.

In the same context, but from a different perspective, Toman and Jemelkova (2003) examine the relationship of energy development with economic development, that is, how energy usage is driven by economic development. They claimed that the linkages among energy and economic growth vary with the stages of the development process and conclude that energy development is an important component of economic development. For instance, at the lowest level of development, energy mainly comes from biological sources (wood, dung, sunshine for drying) and human effort. In the intermediate stages, more processed biofuels (charcoal/fuel wood), animal power and some commercial fossil energy become more important. In the most advanced stages of development, commercial fuels like electricity become prevalent. In contrast to the above study, Stern and Cleveland (2004) adopt a different point of view on the relationship between energy and economic development. Building on a strand of ecological economics, they emphasize that there are limits to both technical progress and substitution possibilities between inputs (i.e. energy, capital, labour, etc.) in the production process (Stern, 1997). Therefore, they suggest that all economic processes require energy as an essential factor of production and conclude that energy is necessary for growth.

Empirical findings, on the other hand, are not unanimous in their results and this leads to a commonly accepted conclusion that the discussion on the interactions of energy with the economy remains open to different interpretations. For instance, the first view has been widely supported by Mozumder and Marathe (2007) for the case of Bangladesh, Ghosh (2002) for the case of India and Masih and Masih (1997) for the case of Indonesia. The empirical work, which is consistent with the second view, includes studies such as Narayan and Smith (2008) for the case of G7 countries, Lise and Montfort (2007) for the case of Turkey and Yoo (2006) for the case of Thailand. The third view, which maintains that both energy consumption and economic development Granger cause each other has been widely supported by studies such as Paul and Bhattacharya (2004) for the case of India, Glasure (2002) for the case of Korea and Masih and Masih (1997) for the case of Korea and Taiwan. Finally, the fourth view which maintains that there is no causality between energy consumption and economic development has been supported by the studies of Altinay and Karagol (2004) and Jobert and Karanfil (2007), both for the case of Turkey.

2. Methodology

The model specification to examine the link between energy consumption and economic development is based on a multivariate framework, which accounts for the important dual role of energy in both the demand and supply side. On the demand side, the model is based on the importance of energy for consumer's utility maximization. Following Hondroyiannis *et al.* (2002) and Medlock and Soligo (2001) the relationship can be expressed in equation (1). On the supply side, the model is based on the importance of energy use as a key factor of production. The relation is adapted from Lee and Chang (2008) and expressed in equation (2).

$$E = f(Y, P, I) \tag{1}$$

$$Y = f(K, E) \tag{2}$$

In (1), E represents energy consumption, and Y, P and I represent aggregate output or real income, energy price and the structure of economy (which is proxy by the share of industry in GDP), respectively. Aggregate output in turn is produced through the application of capital (K) and energy use (E) in (2).

The time series econometric procedures were used in order to examine the relationship between energy consumption and economic development i.e. whether energy consumption will affect economic development or is it economic development drives the demand for more energy consumption in the economy. There are three steps involved in estimating the relationship between energy consumption and economic development. The first step is to test the stationarity of the series or their order of integration in all variables. In this study, Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test will be utilized. The second step is to examine the presence of a long run relationship among all variables in the equation. In this case, the co-integration tests will be conducted to investigate the existence of long-run relationships between the variables. Once the co-integration is confirmed in the model, the residuals from the equilibrium regression can be used to estimate the Vector Error Correction Model (VECM) in the third step. The VECM will be estimated to assess the direction of causality between energy consumption and economic development. The VECM equations take the form:

$$\Delta LE_t = \alpha_1 + \sum_{i=1}^{p}\beta_{1i}\Delta LY_{t-i} + \sum_{i=1}^{p}\gamma_{1i}\Delta LE_{t-i} + \sum_{i=1}^{p}\delta_{1i}\Delta LP_{t-i} + \sum_{i=1}^{p}\phi_{1i}\Delta LI_{t-i} + \sum_{i=1}^{p}{}_{1i}\Delta LK_{t-i} + \theta_{1,1}ECT_{1,_{t-1}} + \theta_{1,2}ECT_{1,_{t-1}} + \varepsilon_{1t} \quad (3)$$

$$\Delta LY_t = \alpha_2 + \sum_{i=1}^{p}\beta_{2i}\Delta LY_{t-i} + \sum_{i=1}^{p}\gamma_{2i}\Delta LE_{t-i} + \sum_{i=1}^{p}\delta_{2i}\Delta LP_{t-i} + \sum_{i=1}^{p}\phi_{2i}\Delta LI_{t-i} + \sum_{i=1}^{p}{}_{2i}\Delta LK_{t-i} + \theta_{2,1}ECT_{1,t-1} + \theta_{2,2}ECT_{2,t-1} + \varepsilon_{2t} \quad (4)$$

$$\Delta LP_t = \alpha 3 + \sum_{i=1}^{p}\beta_{3i}\Delta LY_{t-i} + \sum_{i=1}^{p}\gamma_{3i}\Delta LE_{t-i} + \sum_{i=1}^{p}\delta_{3i}\Delta LP_{t-i} + \sum_{i=1}^{p}\phi_{3i}\Delta LI_{t-i} + \sum_{i=1}^{p}{}_{3i}\Delta LK_{t-i} + \theta_{3,1}ECT_{1,t-1} + \theta_{3,2}ECT_{2,t-1} + \varepsilon_{3t} \quad (5)$$

$$\Delta LI_t = \alpha_4 + \sum_{i=1}^{p}\beta_{4i}\Delta LY_{t-i} + \sum_{i=1}^{p}\gamma_{4i}\Delta LE_{t-i} + \sum_{i=1}^{p}\delta_{4i}\Delta LP_{t-i} + \sum_{i=1}^{p}\phi_{4i}\Delta LI_{t-i} + \sum_{i=1}^{p}{}_{4i}\Delta LK_{t-i} + \theta_{4,1}ECT_{1,t-1} + \theta_{4,2}ECT_{2,t-1} + \varepsilon_{4t} \quad (6)$$

$$\Delta LK_t = \alpha_5 + \sum_{i=1}^{p}\beta_{5i}\Delta LY_{t-i} + \sum_{i=1}^{p}\gamma_{5i}\Delta LE_{t-i} + \sum_{i=1}^{p}\delta_{5i}\Delta LP_{t-i} + \sum_{i=1}^{p}\phi_{5i}\Delta LI_{t-i} + \sum_{i=1}^{p}{}_{5i}\Delta LK_{t-i} + \theta_{5,1}ECT_{1,t-1} + \theta_{5,2}ECT_{2,t-1} + \varepsilon_{5t} \quad (7)$$

where E, Y, P, I and K represents energy consumption, aggregate output or GDP, energy price, the share of industry in GDP and capital, respectively. The symbol Δ indicates first differences. The terms ECT_i refer to the error correction terms, whose coefficients measure speeds of adjustment and are derived from the long-run cointegrating relationships (i.e. $E_t = \lambda_1 Y_t + \lambda_2 P_t + \lambda_3 I_t + \lambda_4 K_t + \mu$) where μ is the stationary residuals). α_i are intercepts, and p is the lag lengths. In each equation, the right hand side variable is regressed against past values of itself and past values of other variables.

The Granger causality test is applied by calculating the F-statistic based on the null hypothesis that the set of coefficient on the lagged values of independent variables are not statistically different from zero. Therefore, if the null hypothesis is rejected, then it can be concluded that the independent variable does cause dependent variable. For instance, if the F-statistic of the Y (Y as an independent variable in the equation (3) is significant at a 5% level, then it can be concluded that there is a short-run causal effect running from Y to E. Besides the detection of the short-run causal effects, the VECM also captures the long-run equilibrium. In the ECT, the cointegrating vector (the long-run cointegrating relationships), represents the long-run equilibrium between variables. Therefore, the coefficient λ_1 for instance, represents the long-run elasticity of Y with respect to E. In addition, the coefficient θ_i of the ECT measures the speed of adjustment towards the long-run equilibrium, or the proportion of the long-term imbalance of the dependent variable that is corrected in each short-run period. Thus, the size and the statistical significance of this coefficient measure the extent to which each dependent variable has a tendency to return to its long-run equilibrium.

In this paper, a joint F test is used to detect the Granger causal relation. On the other hand, the test for the long-run considers restrictions on the coefficient of ECT (since the ECT captures the long-run equilibrium between variables). This test is based on the null hypothesis that there is no Granger causality (i.e. the coefficients are zero, $\theta_i = 0$). The t-test is used to detect the Granger causal relation in the long-run. In addition, the joint significance of the lags of explanatory variable (*Y* and *E*) and the lagged error correction term is also performed to test for the Granger causality. In the energy equation (3), the test for Granger causality of income is $H_0 : \beta_1 = \theta_{1,1} = \theta_{1,2} = 0$. Rejection of the null suggests that GDP Granger –causes energy. In the income equation (4), the test for Granger causality of energy is $H_0 : \gamma_2 = \theta_{2,1} = \theta_{2,2} = 0$. Rejection of the null suggests that energy Granger –causes GDP.

3. Discussion on Findings

Table 1 report the results of the ADF and PP tests on the integration properties of energy consumption, real GDP, prices, share of industry in GDP, capital and labor for Malaysia. Results of the two tests indicate that all series are found to be non-stationary. However, first differences of these variables lead to stationarity, except for labor. These indicate that the integration of energy consumption, real GDP, prices, share of industry in GDP and capital for Malaysia is of order one, i.e. $I(1)$.

Table 1. Results of Unit Root Tests

	Augmented Dickey Fuller Test		**Philips-Perron Test**	
	Level			
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
LE	0.4701	-2.6050	0.5293	-2.6050
	(0.9839)	(0.2800)	(0.9861)	(0.2800)
LY	-1.5258	-0.9148	-1.4735	-1.1400
	(0.5123)	(0.9459)	(0.5385)	(0.9114)
LP	-0.7267	-1.9109	-0.2605	-1.8618
	(0.8300)	(0.6334)	(0.9230)	(0.6589)
LI	-2.3499	-3.5930	-2.2739	-3.4936
	(0.1611)	(0.1510)	(0.1842)	(0.0512)
LK	-1.7191	-1.9983	-1.7191	-1.5752
	(0.4155)	(0.5873)	(0.4155)	(0.7884)
	First Difference			
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
DLE	-7.5150***	-7.5368***	-7.4976***	-7.5348***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DLY	-5.4529***	-5.6153***	-5.3964***	-5.6283***
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
DLP	-3.9293***	-3.9000**	-3.8980**	-3.8355**
	(0.0038)	(0.0198)	(0.0041)	(0.0230)
DLI	-5.1374***	-5.0054***	-4.8350***	-4.5770**
	(0.0001)	(0.0009)	(0.0002)	(0.0032)
DLK	-4.9334***	-4.9986***	-4.8726***	-4.9279**
	(0.0002)	(0.0009)	(0.0002)	(0.0012)

Notes: Figures in the parentheses () are p- value. The asterisks indicate the following level of significance: ***1%, **5% and *10%.

The results of the cointegration tests for the relevant variables are shown in Table 2. Both the results of trace tests and maximum eigenvalue tests point to the same conclusion that there are two cointegrated relationship, at the 5% level of significance. Therefore, there appears to be clear evidence that there are two cointegrating relationship between the variables.

Table 2. Results of Johansen Cointegration Tests

Hypothesized no.of CE(s)	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
Trace statistics	105.8225**	59.7639*	30.0882	13.0521
Hypothesized no.of CE(s)	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
Maximum eigenvalue statistics	46.0585**	29.6757*	17.0361	7.8581

Notes: The asterisks indicate the following level of significance: ***1%, **5% and *10%.

Since all the variables are $I(1)$ and there is evidence of cointegration, the Granger causality test should be performed in the VECM, which allows a distinction to be made between short-run and long-run causality. Recall that the cointegration test suggested the existence of two independent cointegrating relationships. In order to interpret these two relationships as demand and supply equations and to obtain more efficient estimates, a number of constraints for the right-hand-side variables need to be imposed. Let v_1 and v_2 be the two independent cointegrating vectors. Let us relate v_1 to the long-run demand equation, and therefore let us normalise the coefficient of energy consumption in v_1 to one. Note that this restriction implies that energy has a non-zero coefficient in v_1. Similarly, since v_2 is interpreted as the supply-of-output equation, the coefficient of output in v_2 is normalised to be one. In addition, the coefficients of K and L are restricted to be zero in v_1. Finally, the coefficients of P and I in v_2 are both restricted to be 0.

Since there are two cointegrating vectors therefore there exist two ECTs (θ). 1 indicates the error correction term in the demand side and 2 indicates the error correction term in the supply side. A significant ECT coefficient implies that each series in the system is adjusting towards the long-run equilibrium relation and the adjustment is initiated by the combination of all variables jointly.

Table 3 presents the results of short-run causality tests based on the VECM framework for Malaysia. The test, which is referred as the short-run causality test, is conducted using a joint F-statistic for the exclusion of two variables from each equation, as explained above. Since this study aims to examine the causality between energy consumption and income, emphasis is placed only on the relationships between these two variables (energy and GDP). The first hypothesis is that GDP does not cause energy and the second hypothesis is that energy does not cause GDP. The results suggest that the there is no short-run causality between energy consumption and economic development in both energy and income equation.

Table 3. Short-run Granger Causality Results based on VECM

Dependent variable	Source of causation (independent variable)				
	Short-run				
	Δ LE	Δ LY	Δ LP	Δ LI	Δ LK
Δ LE	-	0.9922	0.3746	1.0953	0.2285
		(0.3812)	(0.6903)	(0.3459)	(0.7969)
Δ LY	0.1787	-	0.3584	0.0033	1.2383
	(0.8371)		(0.7013)	(0.9966)	(0.3026)

Notes: Figures in the parentheses () are p- value. The asterisks indicate the following level of significance: ***1%, **5% and *10%.

With regards to the long-run causality test, it can be referred to as the ECT (Error-Correction-Term) test. In this case, let ECT_1 be the ECT corresponding to the long-run demand equation (v_1) and let ECT_2 correspond to the long-run supply equation (v_2). Estimates of the coefficient of the error correction term in Table 4 show that at least one of the ECT terms is significant in the energy equation in Malaysia. This implies that for Malaysia, when there is a deviation from the equilibrium cointegrating relationship as measured by the ECT, it is energy consumption, not output, that adjusts to restore the long-term equilibrium within the system. Therefore, there is evidence that unidirectional causality runs from income to energy consumption in the long run, which implies that economic development stimulates energy consumption in Malaysia.

Table 4. Long-run Granger Causality Results based on VECM

Dependent variable	Source of causation (independent variable)			
	Long-run			
	ECT_1	ECT_2	Joint (ECT and Δ LE)	Joint (ECT and Δ LY)
Δ LE	-0.1976**	-0.0070	-	2.7458**
	[-2.5928]	[-0.2220]		(0.0442)
Δ LY	-0.0041	0.0074	0.1388	-
	[-0.0929]	[0.4029]	(0.9667)	

Notes: Figures in the parentheses ( ) and brackets [ ] are p-value and t-statistic, respectively.
The asterisks indicate the following level of significance: ***1%, **5% and *10%.

In addition to the above tests, the Granger causality test is also conducted, which is referred to the test of joint significance of the lags of explanatory variable and the lagged error correction term. Table 4 presents the Granger causality results for Malaysia. The result shows that the ECT combined with the joint test of GDP in energy equation is statistically significant at 5% confidence level. Therefore this result suggests that there is unidirectional causality running from economic development to energy consumption.

4. Conclusion

This study examines the link between energy consumption and economic development for Malaysia over the period from 1960 to 2009. In order to account for the dual role of energy in both the demand and supply side, a multivariate model of GDP, energy use, energy price, level of industrialisation, capital and labour is utilised. In addition, by allowing more variables to be endogenous, this model accounts for more channels of adjustment than most of the previous literature. Prior to testing for causality, the ADF and PP unit root tests and Johansen cointegration test were used to examine unit roots and cointegration. The evidence of cointegration between the variables suggests that there exist stable long-run relationships among them. Moreover, the evidence of cointegration also implies that Granger causality must exist among these variables either unidirectional or bidirectional. Furthermore, using a vector error-correction model, the direction of short-run and long-run Granger causality was detected.

The empirical results of cointegration test show that energy consumption and economic development are cointegrated. In addition, causality test results reveal that there is a long-run Granger causality running from economic development to energy consumption for Malaysia. This result can be interpreted as follows. Malaysia is one of developing countries experiencing the advancement of the economy. Hence, there has been a particularly rapid growth in energy consumption in the industrial, commercial and service sectors. Thus, it is reasonable to expect that economic development, which takes place mostly in industrial, commercial and service sectors, enhance energy consumption in these countries.

The empirical results of this study provide policy makers a better understanding of energy consumption-economic development nexus to formulate energy policies in Malaysia. In this study, since economic development cause energy consumption, it suggests that the implementation of energy conservation policies may be implemented with little or no adverse effect on economic development. Therefore, there is relatively more scope for energy conservation measures as a feasible policy in Malaysia.

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